High-Efficiency Pleated Filter Technology Improves Parts Quality, Production Yields

Filtration upgrades reduce roughness caused by particulates.

By Joe Warrender, general manager of Warco, Inc., Lake Forest, Ill.

The Electro Chemical Finishing Company (ECF) of Wyoming, Mich., founded in 1978, operates a sophisticated manufacturing facility specializing in the following processes:

- Decorative brass finishing;
- durable Brass II™ finishing;
- decorative chrome finishing;
- gold finishing;
- black pearl finishing;
- physical vapor deposition (PVD) finishing;
- and decorative chrome finishes

ECF's commitment to continuous improvement is achieved in part by a vigorous quality assurance program that includes a validation effort checking both the consistency and quality of its manufacturing systems and products in accordance with A2LA testing laboratory standards. ISO 9002 certified, ECF is setting the standard for creative and technical excellence and stays at the forefront of the industry by implementing new technologies and processes. Quality and on-time production is expected, despite numerous operations with specialty multi-step processes and customized decorative finishes. ECF strives for highly efficient operations that are also environmentally responsible.

ECF had been using horizontal disc filtration systems for a combination of continuous filtration and powder carbon treatment. Numerous attempts were made to improve disc filtration methods, including synthetic cloth media, which proved unsuccessful. Prior to upgrading the process, the quality level for many of the finished parts did not meet ECF's standards. This was partly due to the following unforeseen variables:

Roughness from by-passing of particulates, including carbon, D.E. (diatomaceous earth), process contaminants, buffing compound, media extract, and foreign debris released by worn or loose discs: When filtering minute particles (below 20 micron), bubble-tight sealing surfaces are absolutely critical. For example, a human hair deposited on a sealing surface will bypass <10 micron particles (see Table II).

Substandard filtration and breakdown of the cellulose paper media and/or resin binders due to chemical attack, particularly in acidic or caustic baths: Cellulose paper media performs best in a neutral pH range and has limited usage in lower pH solutions containing five to 10% HCL or H₂SO₄ acids or higher pH caustics. Extractable materials, including wood fiber and/or resin binders, can degrade in a short time, requiring frequent change-outs. For example, caustics are used to liquify wood fiber in paper mills. Blown paper media can result from either material degradation and/or excessive discharge pressure build-up.

Nominal filtration levels (i.e., unspecified particle removal efficiency) with inconsistent process results: Nominal ratings pertain to a specific manufacturer (as an internal reference) and are not an accepted industry standard. Correlating performance in a particular process by means of efficiency removal ratings at specific micron ratings offers definite advantages.

Dislodged D.E.-carbon pack from either corroded parts or a discharge pressure surge from quick-action valve control.

Two primary objectives needed to be accomplished:

- The desire for finer filtration on the existing line to improve the bright nickel and acid copper tanks and reduce roughness from by-passed particulates.
- ECF needed high-efficiency filters for a new Chrome Flash line (involving a pre-plate buffing compound), cleaner tanks, various process tanks, and a final rinse.

ECF's Joe Samsell (plating operations manager) and

CHEMAG™ triplex pleated filter system polishing disc filter on 5,000-gallon acid copper tank.
Dave Mosher (senior process engineer) appointed Joe Arnold (Atotech USA's plating on plastics industry manager) to help refine the process even further. In addition to providing two of ECF's chemistries, Arnold encouraged a review of the filtration methods that led to a trial of an absolute rated, high-capacity pleated filter CHEMAG-CHEMTEX™ marketed by WARCO, Inc.

Other challenges involved maintaining critical bath turnover rates while achieving absolute rated low-micron filtration levels. Higher turnovers increase the probability of capturing damaging foreign particulates from the bath before they can be deposited onto the finished part. The quandary is to achieve high capacities at low micron ratings.

ECF's design for a new line was finalized and installed in June 2006, when CHEMAG-CHEMTEX™ filtration systems were implemented on soak-cleaner and electro-clean (for a pre-plate buffing process), static rinse, acid copper, and nickel process tanks. Spectrometer testing confirmed only two to three specs on a 4.5-in. disc following pleated filtration versus 30 specs with disc media.

Aside from the need for precise filtration efficiency levels, other key commercial issues for ECF included limiting capital expenditures to allow for other process upgrades, finding a compact design to conserve plant floor space, and simplified maintenance procedures to reduce labor costs while avoiding production downtime.

The CHEMTEX™ absolute-rated, high-capacity, high-surface-area pleated filters are constructed of chemically inert, thermally bonded polypropylene media. The precise

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process requirements were met without the nominal filter guesswork. Various process tanks, including bright nickel, acid copper, cleaners, activators, and rinses that were equipped with 0.5-, 5-, and 10-, and 20-micron filtration rated at 99.9% to 99.98% efficiency for primary filtration as well as final stage polishing of disc filters packed with D.E. and carbon. The CHEMAG™ captured a mass of material from a blown disc pack due to a failed center rod, preventing process contamination.

Also, the CHEMTREX™ elements will not degrade from chemical attack, allowing for maximum filter life without concern for media breakdown. Monitoring predetermined flows or pressures is now possible without concern of media degradation. The positive seal of the CHEMTREX™ single O-ring eliminates the risk of by-passing. Consider the target particle size is comparable to powder or bacteria.

The isolated expenditure of the pleated elements initially seemed higher (per single change-out) versus paper discs, but a thorough review of the total filtration operating costs revealed the pleated method was far more cost effective.

Total filtration operating costs and savings include:

- Maximized production yields;
- Reduction in roughness by 20%;
- Capital cost savings of more than 50% vs. disc configurations;
- Smaller footprint saved costly plant floor space (over $200 per sq. ft.) while accommodating limited racking area;
- Fully corrosion-resistant thermoplastic housings with no relining required; the rubber-lined steel disc filters often require relining at $4,000 to $5,000, plus downtime, decontamination, freight, and installation costs;

### Table I

<table>
<thead>
<tr>
<th>Nominal Micron Size</th>
<th>Solids-Holding (per 10-in. x 2.5-in. cartridge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>6 ounces</td>
</tr>
<tr>
<td>10</td>
<td>3 ounces</td>
</tr>
<tr>
<td>5</td>
<td>2 ounces</td>
</tr>
<tr>
<td>2</td>
<td>1 ounce</td>
</tr>
<tr>
<td>1</td>
<td>0.5 ounce</td>
</tr>
</tbody>
</table>

Commonly stated nominal micron ratings of conventional filter media (i.e. standard disc media, string wound or melt blown cartridges, felt bags, etc) are an ambiguous point of reference for filtration levels. Nominal ratings are considered to be only 50% efficient as per the Filter Manufacturer’s Council. Evaluating more accurate measurements, such as the Beta ratio provides an accepted industry standard for repeatability in meeting various process requirements.

*Published by a recognized string wound manufacturer.*

### Table II

<table>
<thead>
<tr>
<th>Micron Size Comparison of Common Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain of table salt</td>
</tr>
<tr>
<td>Human hair</td>
</tr>
<tr>
<td>Lower limit of visibility</td>
</tr>
<tr>
<td>White blood cell</td>
</tr>
<tr>
<td>Talcum Powder</td>
</tr>
<tr>
<td>Bacteria</td>
</tr>
<tr>
<td>Carbon black</td>
</tr>
<tr>
<td>Tobacco smoke</td>
</tr>
</tbody>
</table>

Micron = 1 million of a meter or 0.000009 in.

### Range of Filter Media Fiber Size:

<table>
<thead>
<tr>
<th>Collusolope Paper Media: 50-250 micron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard PP Cartridge: 70-100 micron</td>
</tr>
<tr>
<td>Fibrillated PP Cartridge: 30-45 micron</td>
</tr>
<tr>
<td>Melt Blown Cartridges: 10-90 micron</td>
</tr>
<tr>
<td>CHEMTREX Pleated Elements: &lt;10 micron</td>
</tr>
</tbody>
</table>

* Particle micron sizes qualified by the Filter Manufacturer’s Council; Re: Bulletin 89-5R3 *Micron Rating for Media in Fluid Filters*
Various Beta Rating: Particles Retained Vs. Passing Through the Filter Media

<table>
<thead>
<tr>
<th>Flow In (20)</th>
<th>Flow out (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: β10 = 20.0</td>
<td></td>
</tr>
</tbody>
</table>

The beta ratio is: Number of particles upstream / Number of particles downstream

Referring to the media layer displayed above, assume each particle is 10 microns in diameter and there are 20 particles in solution ahead of the media. One particle is able to pass through the media. Therefore, the beta ratio is: β10 = 20.0 or 90%

<table>
<thead>
<tr>
<th>β10 = 20.0 particles upstream with a diameter of 10-microns</th>
<th>β10 = 20.0 particles downstream with a diameter of 10-microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta Rating</td>
<td>Efficiency</td>
</tr>
<tr>
<td>2</td>
<td>50.0%</td>
</tr>
<tr>
<td>10</td>
<td>90.0%</td>
</tr>
<tr>
<td>20</td>
<td>95.0%</td>
</tr>
<tr>
<td>75</td>
<td>98.7%</td>
</tr>
<tr>
<td>100</td>
<td>99.0%</td>
</tr>
<tr>
<td>200</td>
<td>99.5%</td>
</tr>
<tr>
<td>1,000</td>
<td>99.9%</td>
</tr>
<tr>
<td>5,000</td>
<td>99.98%</td>
</tr>
</tbody>
</table>

In general, the beta ratio provides an accurate efficiency assessment of the filter but does not quantify the solids holding capacity. The solids holding capacity is a function of the amount of media, type of media, porosity, flow rate (flow per unit area), pressure rating and design configuration. While the beta ratio provides a good indication of filter performance, it does not take into account the characteristics of particulate matter, potential media degradation, and effects of flow rate on filter performance. These can best be measured by testing a particular filter design in an actual process system.

Defining test procedures for particle retention as the single pass required by beta (vs. a multi-pass) will also determine filter effectiveness.

Table III

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<table>
<thead>
<tr>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length: 6 feet</td>
</tr>
<tr>
<td>Diameter: 6 inches</td>
</tr>
<tr>
<td>Tubes: 10 each, 1 inch diameter</td>
</tr>
<tr>
<td>Pressure rating: 60 PSI</td>
</tr>
<tr>
<td>Flow rate: 5 GPM*</td>
</tr>
<tr>
<td>Filtrate ports: 3 inches</td>
</tr>
<tr>
<td>Test port: 1/4 inch NPT</td>
</tr>
</tbody>
</table>

Duraflow membranes do not pass solids, even when new, after cleaning or after back-pulsing. Each tube is individually tested for solids passage, flux and pressure prior to assembly into modules.

Duraflow manufactures membrane modules that will retrofit most microfiltration systems including US Filter Memtek, Ionics, K B Technologies and WPS.

Duraflow can also design and build complete custom wastewater treatment systems.

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Operating pressure range for the CHEMAG™ filter is only two to four psig to 20 psig (45-ft. TDH) versus 15 to 20 psig to 35 to 40 psig (90-ft. TDH) for the disc filter;

- Final-stage polishing filters could be added to existing systems (i.e., with minimal pressure drop) using the same pump, motor, and starter.
- Maintenance cost savings—the servicing of each disc filter required three to four men working for one and a half to two hours versus five to 10 minutes for the pleated filter performed by one man—no disc cleaning required;

- Reduction in the loss of process chemicals—drained liquid from the CHEMAG™ filter vessel is returned directly to the process tank and all contaminants are captured inside the element;

- Extended life of cleaner tank chemistries with no tank build-up (present with string wound cartridges);

- Reduction in waste disposal costs with longer duration between change-outs and low media material mass.

The effectiveness of the CHEMAG-CHEMTREX™ filters has greatly enhanced ECF's production line.
with higher process efficiency, lower capital cost, along with reduced maintenance and operating expenditures. ECF is impressed by the quality of robust thermoplastic construction in the CHEMAG filtration systems and seal-less mag-drive pumps. The small footprint and ease of change outs are seen as primary advantages.

WARCO's CHEMAG-CHEMTREX™ absolute-rated filters have eliminated the filtration variable and given ECF total process control that they demand for their customers with low micron filtration levels that eluded them in the past.

**FILTRATION APPLICATION DATA**

**Filtration Affinity Rule No. 1:** Media life within the same process conditions (e.g., comparable bath chemistry, production volume, flow rate, micron ratings, media flow characteristics, etc.): **Doubling media surface area will quadruple life.**

**Filtration Affinity Rule No. 2:** Following the same exponential factor, media life predictability can be determined as follows:

- **As media pressure-drop doubles (at clean start-up) life is reduced by 50%.**

**Verifying Media Pressure Drop:** Confirm start-up media pressure drop by checking the pressure at the filter vessel (before and after installing media) to determine the increase in pressure.

Therefore, undersized filters and low-porosity media will require excessive start-up pressures that will never achieve the maximum filter life due to one of the following limiting factors:

- The required pressure rise will exceed the pressure capability of the media, housing, or pump.
- The excessive filter pressure drop will diminish pump capacity below the minimum bath turnover rate.

A low start-up media pressure drop of one to two psig (or less) will significantly increase solids holding capacity due to the lower density surface layer. Maximum filter life will be achieved, well within the performance limits of the media, filter housing, and/or pump.

**Note:** Pressure drop with a D.E.-carbon pack is typically higher than carbonless filtration due to the blinding nature of powder carbon.

ECF did not consider string wound cartridges (see Table I) for fine filtration (below 20 micron nominal); however, coarser cartridges are used in other areas of the plant. The string wound filament size (i.e., 30 to 100 micron) does not lend to low micron filtration. As the micron rating in a string wound cartridge is reduced, the solids holding capacity drops significantly due to lower porosity from the more tightly wound string and higher core density. It becomes more of a surface filter rather than a depth filter. Also, the sealing mechanisms are another limiting factor.

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Joe Warrender is general manager of WARCO, Inc., based in Lake Forest, Ill. He has 30 years of experience in applying advanced filtration technology and seal-less mag-drive pumps to the electroplating, metal finishing, automotive, aerospace, and electronics industries. He may be reached at sales@warcoinc.net.

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